End Of Life Analysis

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Abstract

Under the new European WEEE directive there will be strict limits for disposal of electrical goods to landfill etc. The area of analysis which takes into account the full life cycle of products and components is called "end of life" analysis. The idea is that the economic life of components is longer than the life of the initial use. To use this value and to meet such directives a radical approach to recycling is needed. Modules, components or materials may be reused. This leads to a complex feedback to earlier stages of the supply chain. End of life analysis should predict the life of components etc with an objective of reuse etc. It can be considered as an extension of predictive maintenance and signature analysis in reliability. The ideal is to have cheap and fast tests on the basis of which decisions about reuse etc can be made. The implications for design are considerable.

1 The urgency of WEEE

The EC Directive on Waste Electrical and Electronic Equipment (WEEE) was agreed on 13 February 2003 and with amendments is likely to come into effect. It is driven by "the need for promoting waste recovery with a view to reducing the quantity of waste for disposal and saving natural resources, in particular by reuse, recycling, composting and recovering energy from waste...". Governments have programmes of induction in the directives and companies in the relevant sectors are urgently addressing the implications for product development. These implications are a radical extension of the current approaches to the product life cycle.

The life cycle really becomes a cycle. Components can be recycled in various ways: component reuse, material reuse, use as a source of energy etc. The more complex life cycle drives a more complex supply chain and affects the links in the chain and the contractual relationships. New business models are needed to take account of the change and based on a better understanding of the risks and risk sharing.

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2 The effect on reliability

The best place to start is with re-use. Parts and components come back into a factory and are combined with new parts and components to build a "new" product. Thus, the concept of life-time is already affected. A part may have more than one life in the normal sense. A simple way of saying this is that the economic life of a product is longer than its first use.

At the time of possible reuse a decision has to be made about whether a part is good enough to be reused or must be rejected. It could also, of course, be reconditioned or repaired before being reused. It will certainly be cleaned. The area of predictive maintenance needs to be extended to predictive reuse. Enough must be known about the probable effective life of a component to forecast whether it can be used and reduce testing to a minimum. Reuse decisions have to be made quickly so as not to delay production. The area of reliability-based decisions making for reuse waste disposal is called "end of life" analysis. It too early to give a more precise definition, given the complexity and the legal and economic uncertainty.

3 Signature analysis and hierarchical modelling

The main technology used in predictive maintenance is "signature analysis". Measurements on products such as engines exhibit particular signatures and departures from these signatures or the appearance of special features in the signals can indicate the possibility of failure ahead of actual failure. When dynamics characteristics which are being measured signature analysis can be considered as branch of signal processing. Electrical, vibration and sound are typical measurements.

In line with quality improvement concepts the signature should be linked to cause of (possible) failure, that is it should give traceability. In order to make this effective there must be a considerable amount of off-line modelling. The methodology in the project is to combine a signal processing style of measurement with designed experiments in order to build models which related high level signal features to low level failure and degradation.

3.1 The importance of function

The importance of linking the modelling to the engineering cannot be over-estimated. Within engineering "function" has become a key concept in recent years. In quality improvement "Quality Function Deployment" and "Design Function Deployment" are useful methods. Consideration of the function of a component or higher level module is very useful in determining failure modes, suggesting the right type of measurement and helping to build hierarchical models. There is a hierarchy of engineering function underlying any model of failure. Failure can be defined as a failure of functional performance: "I just want the car to get me there".

3.2 Wavelets and feature extraction

Wavelet analysis is used to decomposed (deconvolute) dynamic signals into components, each with its own wavelet coefficient. Using the discrete wavelet transform (DWT) the raw signal is decomposed into components which represent the fine structure of the signal and noise, which is removed by thresholding methods (denoising). The frequencies are represented by the local scaling of the wavelet and time by the time-shifted wavelet. The inverse transformation is used to build up an estimate of the "true" signal

The methodology consists in extracting particulary time or frequency features which can be related to particulary failure modes or degradation. Multivariate analysis can be used either directly on the wavelet coefficients or features, such as peaks, to further reduce dimensionality.

The aim is to use the high level feature detection for in real time for fast testing at the end of life decision point. The features would hold the information about the lower level functional failure or material quality.

4 A case study

Flextronics International in Venray, The Netherlands, has the responsibility for the development of end of life analysis for photocopiers and other products. The aim, with partners, is to build up a general purpose protocol using a combination of reliability methods, experimental design, signal processing, field data analysis.

Some experiments are described on functions of a photocopier finisher module which has three main components: *stapler motor, nip motor* and a *solenoid*. Following some Failure Mode and Effects Analysis to aid understanding of the function an experiment was performed under different operating which included load (volume/weight of paper) and the introduction of degraded components.

The current amplitude was used as a main output. The peak amplitudes were related to different functional activities during the cycle. For example one peak is clearly associated with the *spring* load, the point at which the staple first cuts into then paper before stitching: Figure 1. At this point the signal dominates the first 6 scale levels of the wavelet analysis, so that one can consider the signature having at least 6 dimensions. That is to say the peak itself is a complex feature. One or more of the relevant coefficients which compose the peak can be analysed against the factors in the experiments or combined using multivariate methods into a single component.

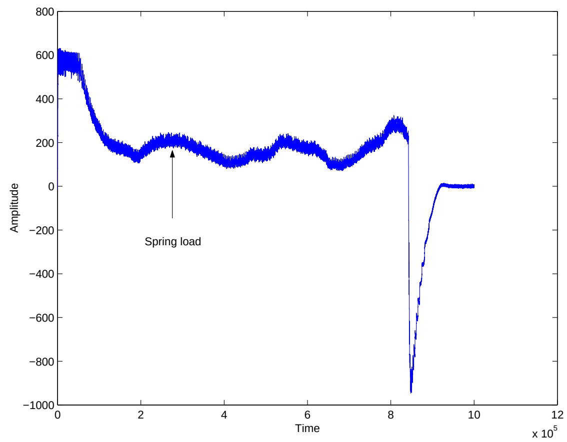

Figure 1: Current signal of the stapler motor and spring load peak

5 The implications for design

End of life analysis heralds a new era for design, as extensions of design for reliability and robust design, which must take into account the after-life of all components. It must be made easy to disassemble components, retrieve materials or reuse them to generate energy. Components which are probably going to be reused need to be robust and reliable for two, three... lives. Components with a single life can be cheaper and more easily reused as material or energy. Warranty and maintenance will change. Perhaps the concept of a product itself need to be revised to be more fluid and adaptable. Components from one product may be reused in a different product. Sourcing components will included reusable components. The market place for components will increasingly be a mixture of the old and the new.

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